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ROOTS OF A PONDEROSA PINE

by

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Describes and illustrates the nature, extent, and location of the roots of a 60-year-old ponderosa pine in central Idaho. Compares the data with those from other investigators working with ponderosa pine and other species. Considers some silvicultural implications.

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ROOTS OF A PONDEROSA PINE

James D. Curtis [1]

At best a silviculturist has difficulty in deciding whether a tree should be cut or left in a stand. Actually he can see only half the tree--the half that is above ground. He knows neither the extent nor the condition of the half beneath ground even though it may, to some extent, be revealed by the crown. He uses various criteria to make his decision depending on the species, age, density, composition of the stand, the condition of the tree, and the market for forest products. And yet, the condition of the aerial part of the tree depends on the condition and arrangement of the subterranean parts. For mature and overmature stems this disadvantage is not very important, but familiarity with and knowledge of tree root systems in weedings, improvement cuttings, and thinnings enable the silviculturist to gain proficiency in marking and thus leave his stand in a better condition than he would otherwise leave it.

An obvious deficiency in silvical information about many tree species is a lack of knowledge of the development, arrangement, and functioning of root systems, particularly in the 25th to the 75th year age group. This deficiency may be due to the work involved in exposing all the roots of a sizable tree without undue damage. Again, it is virtually impossible to find a "typical" tree. Our knowledge of root systems of middle-aged North American conifers in natural stands is confined, with several notable exceptions (Berndt and Gibbons 1958; Bishop 1962; Cheyney 1932; Heyward 1933; Horton 1958; McQuilkin 1935; Woolsey 1911; Yeager 1935), to windthrown individuals and others whose root systems have been exposed by soil disturbance caused by land clearing, roadbuilding, and massive or limited sloughing. Windthrown trees are a precarious basis for judging the nature of a species' root habit, but they may provide a clue (Büsgen and Münch 1929).

The causes of tree root variation are the depth and nature of soil and the height of the water table which, in turn, determine (1) the availability of oxygen and moisture, and (2) the frequency and nature of obstructions through which roots cannot pass (Büsgen and Münch 1929; Kramer 1949). Several investigators point out that although a species usually has a typical root system, this trait is by no means consistent (Berndt and Gibbons 1958; Büsgen and Münch 1929; Horton 1958; Jeffrey 1959; Yeatman 1955). The difficulty arises in knowing when this variation occurs because obviously it can modify silvicultural practice. To guide his choice, the tree marker can observe only surface configurations, soil characteristics, and condition and appearance of the tree. Nevertheless, if he can keep in his mind's eye the general nature of the root system of the species with which he is dealing, he will do a better job of marking.

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[1] Research forester, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, stationed at Boise, Idaho.

What *is* the arrangement of a ponderosa pine root system?

This question and the limited study of root systems of this species (Woolsey 1911; Yeager 1935) prompted the writer in 1950 to investigate the root system of a 16.9-inch d.b.h., 60-year-old ponderosa pine 67 feet high.[2] The tree was a vigorous dominant specimen growing in a stand supporting a basal area of 95 square feet per acre in Boise Basin Experimental Forest, Idaho City, Idaho. The exposure was easterly and had about a 15-percent slope. Availability of a good water supply and sufficient equipment enabled most of the excavating to be done by washing. The coarse granitic loam soil contained many large aggregates; as excavating proceeded, it became apparent that the tree was beside a diorite formation. Hence, it became necessary to alternate the washing with hand-picking tools and to vary the pressure of the water stream to avoid injury to the small roots. The excavating started in mid-July and continued intermittently until September 6.

Besides the diorite, the soil included sandy loam and gravelly loam. Most of the lateral root system was growing in the sandy loam. The diorite formation was near the surface at the downhill base of the tree, but also extended up the slope above it. On the uphill side the coarse gravelly loam covered a gravel bed to a depth of a little more than 2 feet.

The direction of main lateral root growth appeared to be closely related to the soil type in which the roots grew. In the loose gravelly soil, which had small stones throughout, the roots grew in a generally straight-line direction. Where the soil was compacted and contained larger stones, the root direction changed often. Main root growth in the diorite formation followed fissures and cleavage planes. The ends of several main laterals were dead up to 43 percent of their length and therefore were not mapped.

All the main lateral roots were excavated, their directions determined, and their diameters and depths measured. Wherever a main lateral forked, only the larger fork was followed and mapped. The taproot and sinker roots were traced as far as hardness of the substratum permitted--never more than 50 inches. Secondary laterals were tallied by diameter by 5-foot lengths along the main laterals. Sections of several main laterals near the trunk were cut and removed after measurement to facilitate excavation of roots close to or beneath them. Because of the recording and plotting system followed, the delineation of the root system and the tally of the roots present a conservative picture.

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[2] The author gratefully acknowledges assistance of Richard H. LeDosquet, Bureau of Land Management, Fairbanks, Alaska, in the excavating.

The appearance of the root system in plan and in west elevation and a projection of the live tree crown perimeter are shown in figure 1. Several interesting facts are readily apparent:

1. The arrangement and extent of main laterals are uneven.

2. The root system extends horizontally further than the radial spread of the tree's crown.

3. Most lateral roots and their rootlets are located within 18 inches of the ground surface; only the main taproot and the sinker roots penetrate to greater depths.

4. Some of these lateral roots extend considerable distances from the trunk (53 feet straight line) and can be within an inch or two of the mineral soil surface.

5. The horizontal area designated by joining the adjacent live ends of lateral roots is larger (5.4 times) than the projection of green crown.

6. More of the root system is on the downhill side than on the uphill side, an observation recorded by others (Berndt and Gibbons 1958; Büsgen and Münch 1929; McMinn 1955[3]).

7. Most of the sinker roots lie close to the stem.

8. The taproot forks at a depth of about 25 inches.

Figure 1 could not show that the proximity of other trees apparently did not affect the direction of the main laterals of the study tree.

Table 1 records the numbers of rootlets by their diameter and their distance from the main trunk. From this table and from root measurements the following facts can be noted:

1. More than 73 percent of primary and secondary laterals were located in 18 inches (between 6 and 24 inches beneath the ground surface) of soil.

2. More than 92 percent of primary and secondary laterals were found in the first 24 inches of mineral soil.

3. Nearly 85 percent of the secondary roots were in the 0.10- to 0.25-inch diameter class, and 98 percent were 1 inch or smaller in diameter.

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[3] McMinn, R. G. Studies on the root systems of healthy and pole blight affected white pine (Pinus monticola Dougl.). Canada Dept. Agr. Sci. Serv. Interim (unpub.) Rpt., 31 pp., illus. 1955.

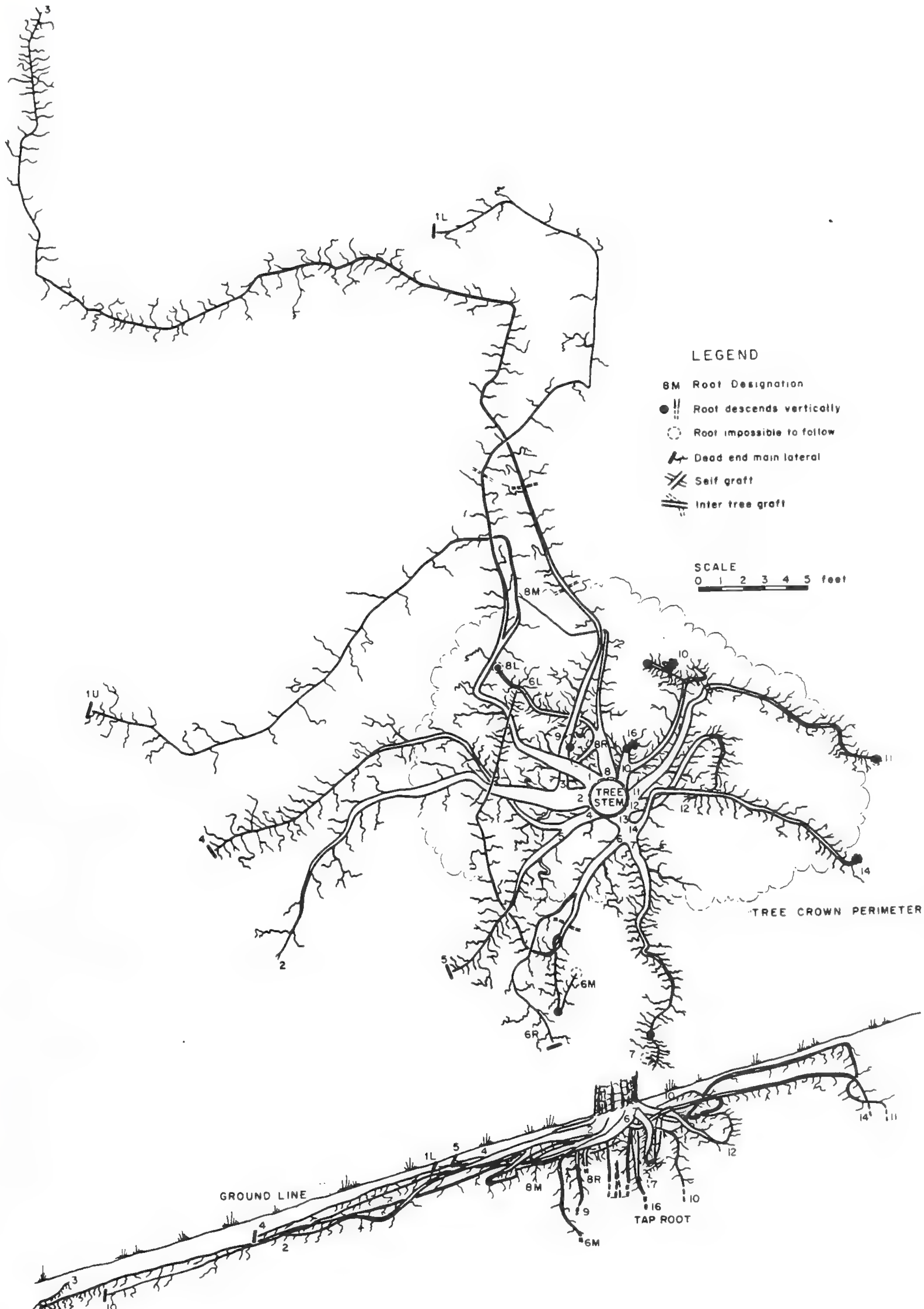

Figure 1.--Root system of a 60-year-old ponderosa pine in plan (above) and in elevation (below).

Table 1.--Numbers of rootlets on main laterals by diameter and distance from main trunk

Root diameter (inches)	Distance from main trunk (feet)														Total	Distribution
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70		
	Number															Percent
0.10-0.25	249	311	198	113	29	29	68	63	37	17	23	14	13	43	1,207	84.6
.26- .50	43	38	14	11	6	5	7	5				2			131	9.2
.51-1.00	26	11	8	4	1	4	1	2	1						58	4.1
1.10-1.50	15	3	1												19	1.3
1.60-2.00	8														8	.6
2.10-2.50	1														1	.2
2.60-3.00	2														2	
Total	344	363	221	128	36	38	76	70	38	17	23	16	13	43	1,426	
Percent	24.1	25.5	15.5	9.0	2.5	2.6	5.3	4.9	2.6	1.2	1.6	1.1	.9	3.0		100.0

4. Close to 50 percent of secondary laterals were within 10 feet of the tree stem, 65 percent within 15 feet, and 75 percent within 20 feet. Similar relations have been recorded for Scots pine (Kalela 1954). Moisture measurements made at the end of the growing season in a 16-year-old loblolly pine plantation suggest that this species has a similar pattern of rootlet density. Available soil moisture was greatest at points furthest from the stems and lowest a few inches from them (Douglass 1960).

5. Lengths of main laterals varied from 45 to 797 inches; three exceeded 700 inches, and eight exceeded 200 inches.

6. The total of live main lateral root lengths was 4,801 inches.

7. Most of the sinker roots were within 3 feet of the stem (see fig. 1).

8. In addition to the main laterals (fig. 1), 19 other roots emanated from the main root collar. All of these were less than 3 inches in diameter; 14 were less than one-half inch in diameter, and none were of significant length. They may well have been adventitious roots.

The taproot of Pinus ponderosa is believed to have four xylem strands and the lateral roots may have two, three, or four.[4] Because secondary laterals usually originate opposite these xylem strands, and because in this instance the roots are assumed to be triarch, figure 1 in plan shows only two-thirds of the total root tally and in elevation only one-third.

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[4] According to Dr. K. Esau, Department of Botany, University of California, Davis, California, through courtesy of Dr. N. T. Mirov, formerly with the Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

During the excavation, several general observations were made. In spite of the large number of rootlets measured, very few growing tips were found, a condition common on plants in soils having little surface moisture (Kramer 1949). The sinker roots, together with some laterals, disappeared into crevices in the diorite or hardpan and could not be traced to their ends. Most, but not all, main laterals developed independently and avoided their neighbors (fig. 1). Eight instances of what appeared to be true intraspecific grafting and one interspecific (with aspen) were noted as well as several instances of self-grafting--phenomena that have been recorded for other species (Bormann and Graham 1959). The taproot was excavated to a depth of 35 inches; the diorite prevented further digging. Sinker roots sometimes grow deeper than taproots (Büsgen and Münch 1929), but no comparisons could be made in this study.

A light surface fire had burned through the stand 5 years previous to the excavation, and apparently had killed some of the root ends. However, the dying of roots and their parts from various causes is apparently a common occurrence (Büsgen and Münch 1929).

A striking feature of the exposure of the main laterals was the competition provided by the dense network of herbaceous and woody ground cover in the top 18 inches of soil (fig. 2). In fact, this competition, judged by the number of rootlets tallied, and

Figure 2.--A main lateral 45 feet from the main trunk and 10 inches beneath the soil surface lies just below this root mass. This root has few secondary laterals and little taper, giving the "ropelike" appearance described by other investigators.

the number observed on the laterals of neighboring trees, was much greater than that of other tree roots. A similar situation was recorded in the Lake States where, out of a total of 33,829 inches of rootlets in a square yard, more than half, or 18,879, were other than tree roots (Cheyney 1929). Elimination of this competition might have a pronounced effect on growth of the stand. A correlation between the amount of this ground cover and diameter growth of the stand above it was found in preliminary studies in Oregon.[5]

The tenacity for life of trees is well known (Kramer 1949), but it is illustrated quite forcefully by this tree. The root system described here was exposed and partly eliminated in 1950; only the forked taproot and some sinker roots remained. In the 10 years since excavation, radial growth has been only 0.15 inch compared to 1.0 inch during the 10 years prior to excavation. Although the crown had an unhealthy appearance for several years, the crown color and annual height growth now appear to be normal.

Inasmuch as ponderosa pine is considered a species whose root habits are fixed by heritability (Kramer 1949), some silvicultural guides can be noted for consideration.

1. Many main laterals are close to the surface and can be injured, even severed, by surface fires and logging activity.

2. The root system extends over an area several times the size of the projected crown. For 18 eastern hardwood trees (17 to 104 years old) this ratio was 4.5 to 1 (Stout 1956). For this ponderosa pine it was 5.4 to 1. Competition may therefore be greater beneath ground than above it because root systems have more overlapping than crowns. Thinning could decrease this competition.

3. Because the greatest concentration of secondary laterals is within a radius of 10 feet of the bole, and because all the sinker roots are close to the stem (on this tree, about 3 feet from it), thinning near selected crop trees should produce the greatest benefit. This effect of release in terms of diameter growth has been demonstrated for central Idaho (Curtis 1952).

4. Root grafting can be lessened by thinning, but this would be entirely on a chance basis. Any benefit to uncut trees would depend on the respective sizes of the trees cut and left.

5. Ponderosa pine is recognized as an inherently taprooted species, but it can also have sinker roots close to the trunk.

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[5] Correspondence with E. L. Mowat, formerly with the Pacific Northwest Forest and Range Experiment Station, Bend, Oregon.

6. There appeared to be more competition for the rootlets of the tree's main laterals from roots of lesser vegetation than from the roots of other trees. Judicious early thinning and application of selected herbicides might reduce this competition from the undergrowth.

7. The area contained within the perimeter of the primary lateral root ends is not fully utilized by the tree. Because roots develop in soil where there are moisture and nutrients (Kramer 1949), roots of neighboring trees can encroach into zones presently unoccupied.

SUMMARY

The root system of a 60-year-old, 67-foot-high ponderosa pine was excavated for examination in central Idaho. Soil removal was achieved by washing and careful picking. All main lateral roots were exposed, mapped, and measured. The taproot and sinker roots were traced as far as hardness of the substratum permitted--never more than 50 inches. Secondary laterals were tallied by 5-foot lengths along the main laterals. More than 3 percent of the primary and secondary laterals were located between 6 and 24 inches beneath the ground surface. Ninety-eight percent of secondary roots were 1 inch or smaller in diameter. Lengths of laterals varied from 45 to 797 inches. The root system extended over an area 5.4 times the size of the projected tree crown. More of the root system grew on the downhill side than on the uphill side.

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